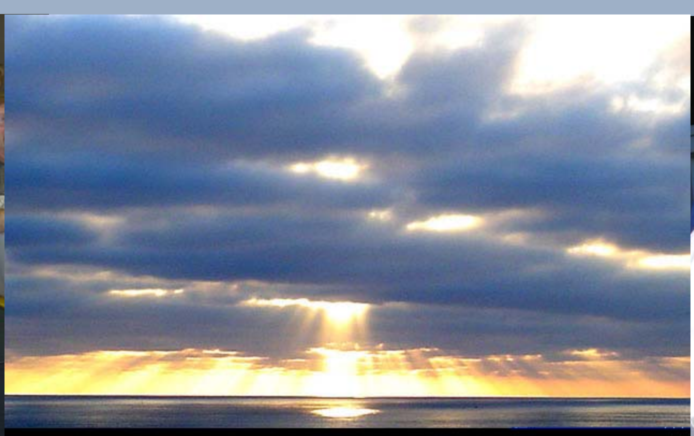
Utilization of Unmanned Aerospace Vehicles for Global Climate Change Research

Scripps Institution of Oceanography

San Diego, California - August 3 & 4, 2004

An InnovationLabs Collaborative Session



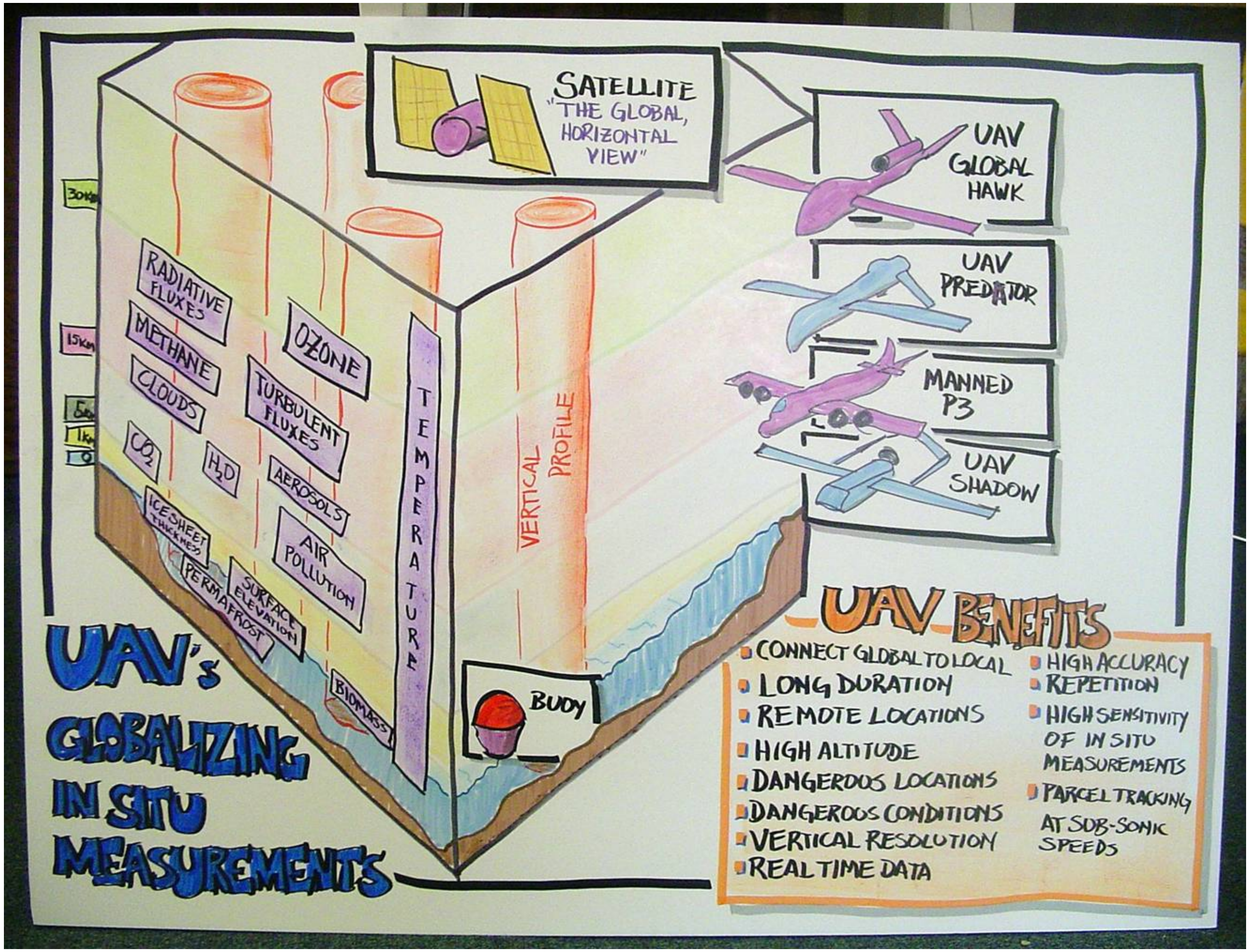
Session Overview

On August 3rd and 4th, 2004, representatives from NASA, NOAA, the Department of Energy and a variety of researchers and scientists gathered in San Diego to explore the role that Unmanned Aerospace Vehicles (UAVs) will play in measuring and modeling global climate change and follow-on long term monitoring. This collaboration represents the beginning of a new relationship between these agencies and the scientific community.

The session began with a series of presentations about the program objectives of the three agencies, about the requirements for a research program, and about the current state of UAV capabilities. The group then divided into teams to identify scientific goals and observation requirements in each of four areas: Climate, Atmospheric Observations, Global Observations, and Ocean & Land Surface. (All of these areas are presented in the following pages.)

To illustrate the next steps in further developing these areas, the group concentrated on three topics: Carbon Fluxes, Climate Profiles, and - to illustrate the synergy between climate research and other topics with high societal benefit - High Impact Events. These three areas were sub-topics in the initial climate areas. Summary illustrations of each of these topic areas are included in the final section of this presentation.

Summary Illustration – The Role of UAVs



Benefits of UAVs

The participants in the workshop identified several key advantages that UAV-based observation platforms offer over satellites or piloted aircraft.

Advantages associated with suborbital (UAV and piloted aircraft) observation systems

- High accuracy of measurements
  - Atmospheric in situ measurements
  - High sensitivity of in situ measurements
- Multiple variables with accuracy & flexibility
  - High altitude or low & slow
- Parcel tracking at sub-sonic speeds
- Reduced antenna/power requirements for high-bandwidth data communication

Advantages associated with UAV observation systems

- Long-duration flights
- Remote locations
- Lower consequences of loss (vs. pilots and satellites)
  - Dangerous locations
  - Dangerous flying conditions
- Improved performance
  - Repetition capability (pilot burnout)
  - Specialized instruments cannot be used with pilots
    - Hazardous active RF
- Global vertical resolution & profiling


Topic Area - Climate

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
1	Understand sensitivity of climate to forcings (solar, CO_2, Albedo, clouds, aerosols, and H_2O)	Improve prediction capabilities and our understanding of emerging data to support international and domestic policy decisions	Profiles of state and forcings, re: atmospheric	High resolution In situ measurements over large regions and long duration low and slow risky flight conditions repetition capability
2	Determine sources and sinks of CO_2 and methane	Determine which regions of the world are sources and sinks of carbon as a driver of climate change	CO_2 Methane state variables and dynamical tracers in the boundary layer and free troposphere	High sensitivity in situ measurements coupled with long range low and slow risky flight conditions

Topic Area – Atmospheric Observations

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
1	Role of carbonaceous and other aerosols in global warming, water budgets, sea-ice and glacier melting	Habitability	High spatial and temporal resolution observations for studying spatial gradients and vertical profiles with long endurance:	routine observations of vertical profiles covering diurnal cycle
		agriculture (water availability and photosynthesis)	physical, chemical and radiative properties of elemental and organic carbon, other aerosols, and air pollution	long duration gradients c> 12-24 hours
		Health impacts of human population	determine emission sources of aerosols	parcel tracking at subsonic speeds
		Precipitation/soil erosion	metaphysical properties of clouds and precipitation	high altitude and remote locations for observations
		energy policy	radiative fluxes	
		improvement of aerosol treatment in general circulation models (GCMs)	u,v,w and turbulent fluxes	

Topic Area – Atmospheric Observations

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
2	Role of water vapor and cloud-radiative feedbacks in climate change of next few decades	improved treatment of clouds and H2O in GCMs	High spatial and temporal resolution observations of spatial gradients and life cycles of low, mixed-phase, ice clouds and deep convection and their environment	routine observations of vertical profiles covering diurnal cycle
		Attribution of human impact on observed climate change	high precision and accuracy H2O from surface to troposphere	long duration gradients c> 12-24 hours
		Energy policy	metaphysical properties (phase, shape, size) of clouds	high altitude and remote locations for observations
		Satellite evaluation	macrophysical properties	
			radiative fluxes	
			turbulent fluxes of u, v, w, q, T	
			physical, chemical and radiative properties of ice nuclei (IN) & cloud condensation nuclei (CCN), including elemental and organic carbon	

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
3	Quantify changes in chemical composition of atmosphere	Chemistry effects on radiation balance, including aerosols	High spatial and temporal resolution observations of vertical and horizontal gradients of	high altitude observations
		Ozone (O3) as ultraviolet (UV) filter	O3, source gases, reactive gases and aerosols,	vertical, high-resolution profiles
		Air quality	turbulent fluxes of u, v, w, q, T	long-range gradients
			radiative fluxes	
				Enabling Attributes
				Adequate range, endurance, payload
				Affordable
				Reasonable airspace access
				Ability to do vertical profiling (near surf to high altitude)

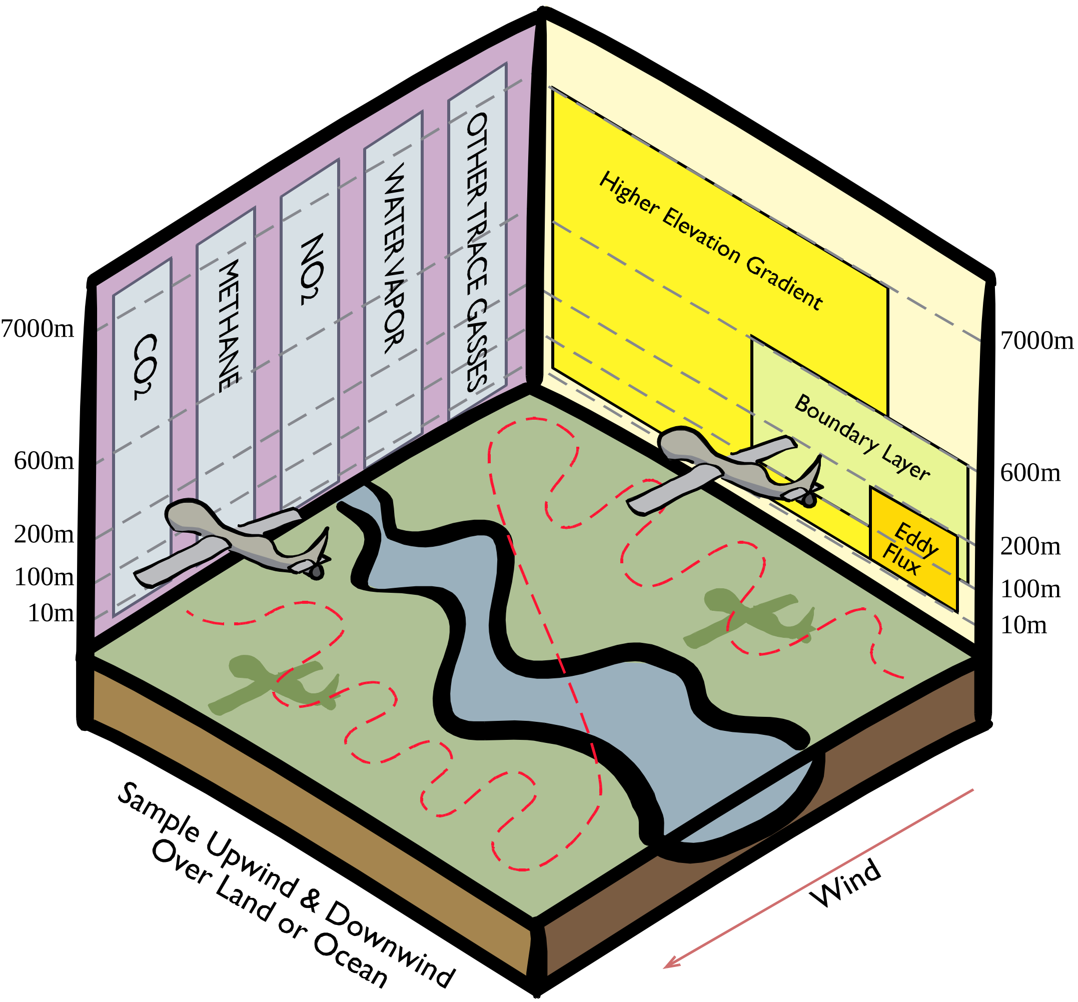
Topic Area – Global Observations

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
1	Improvement of high impact weather forecasts at 1 day to two week lead times	Mitigate vulnerability of society, economy and environment to high impact weather	Routine and adaptive observations where current in situ profiles are sparse and satellite coverage is limited	UAV provides a rapid response platform that has regional to global deployment capability
2	Improved observations and prediction of climate variability and change	Better climate change detection, attribution, and prediction in support of policy decisions	Sustained global high quality all weather profiles of atmospheric composition (aerosol, water vapor, cloud water and trace gases) temperatures and radiation	UAV provides vertically resolved sustained measurements on an affordable global scale from boundary layer to lower stratosphere
3	Advanced knowledge of critical physical processes involving aerosols, clouds, precipitation, and radiation	Improved prediction of societally-relevant aspects of climate and weather	Detailed high resolution sampling of aerosols, clouds, precipitation, etc., in support of process-focused field experiments	The ability to measure multiple variables with greater accuracy of detail and flexibility

Topic Area – Ocean and Land Surface

Focus	Science Goal	Benefit to Society	Observations Required	Why UAVs
1	Models and predictions *Climate Change Science Program (CCSP) Priorities Gas fluxes response and feedback	Early warning negotiation Info	Trace gas fluxes of: CO_2 H20 Methane Bromine Sulphur Sulphur compounds	Vertical resolution Remote Low level in situ data High spatial res. ~= to 1 meter scale Can operate in all conditions
2	Cryosphere response & feedback	Early warning negotiation/ info awareness	Polar Ice sheet thickness Accumulation rate Surface elevation Sea ice and snow thickness	Remote access Repetitive High spatial and temporal resolution Specialized instruments that cannot be operated on piloted aircraft or satellites
3	Response and adaptive management Biosphere response Agriculture Fisheries and Coral reefs as indicators of climate change	Economy Ecosystem stability sustainability	Visual IR Multi-spectral Hyper-spectral Lidar Soil moisture Fuel biomass & moisture Aerosol and gas measurements	-Remote locations -Proximity for detail -Calibration/ground truthing -Repetitive measurements – pilot burnout -Targeted to special events -Real time data needs

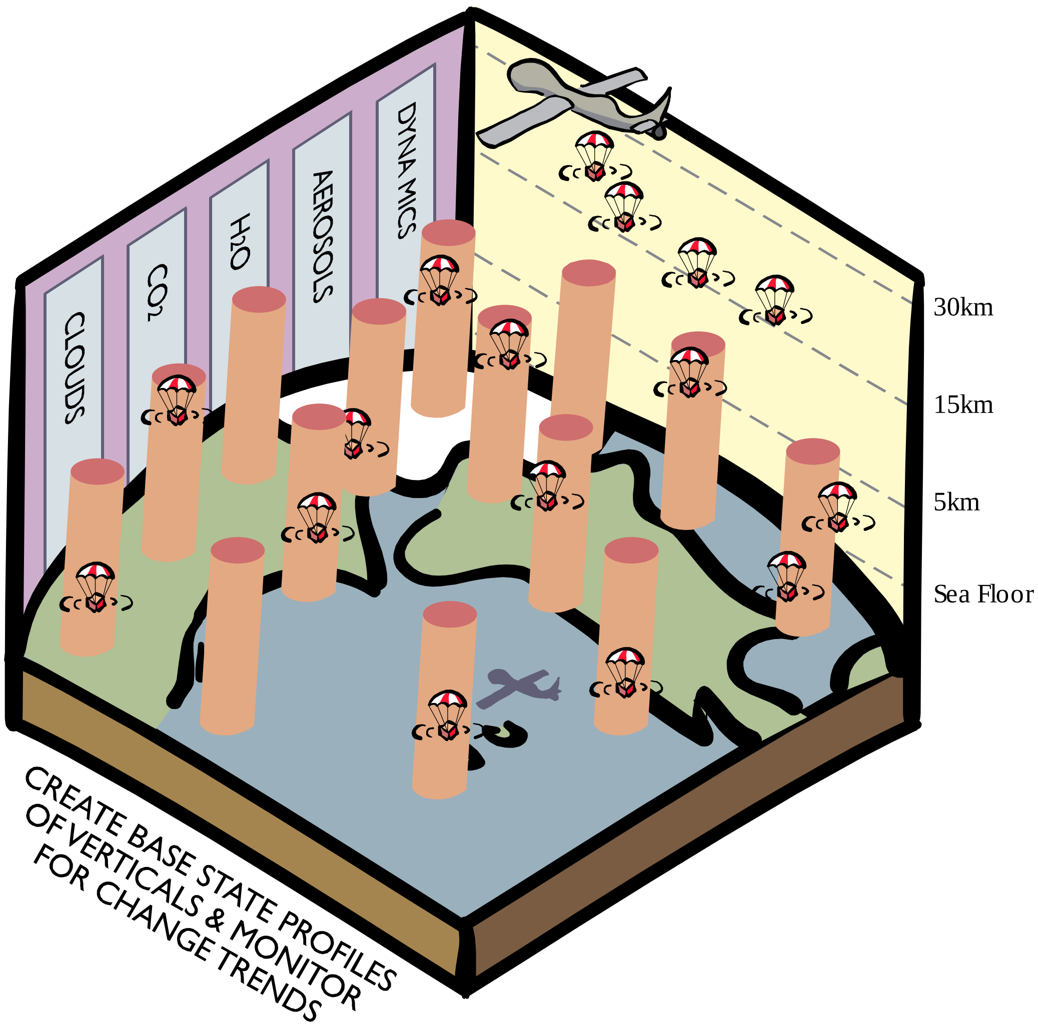
Carbon Fluxes



Obstacles

- FAA
- Miniaturization (IRGN, GPS-3D, Data Storage or Download)
- Communication
    - Near Real-Time Packets
    - Data Management & Distribution
    - Data Management Models
- Cost
- New Sensors (e.g. Methane, Nitrous Oxide)
- Duration at low altitude

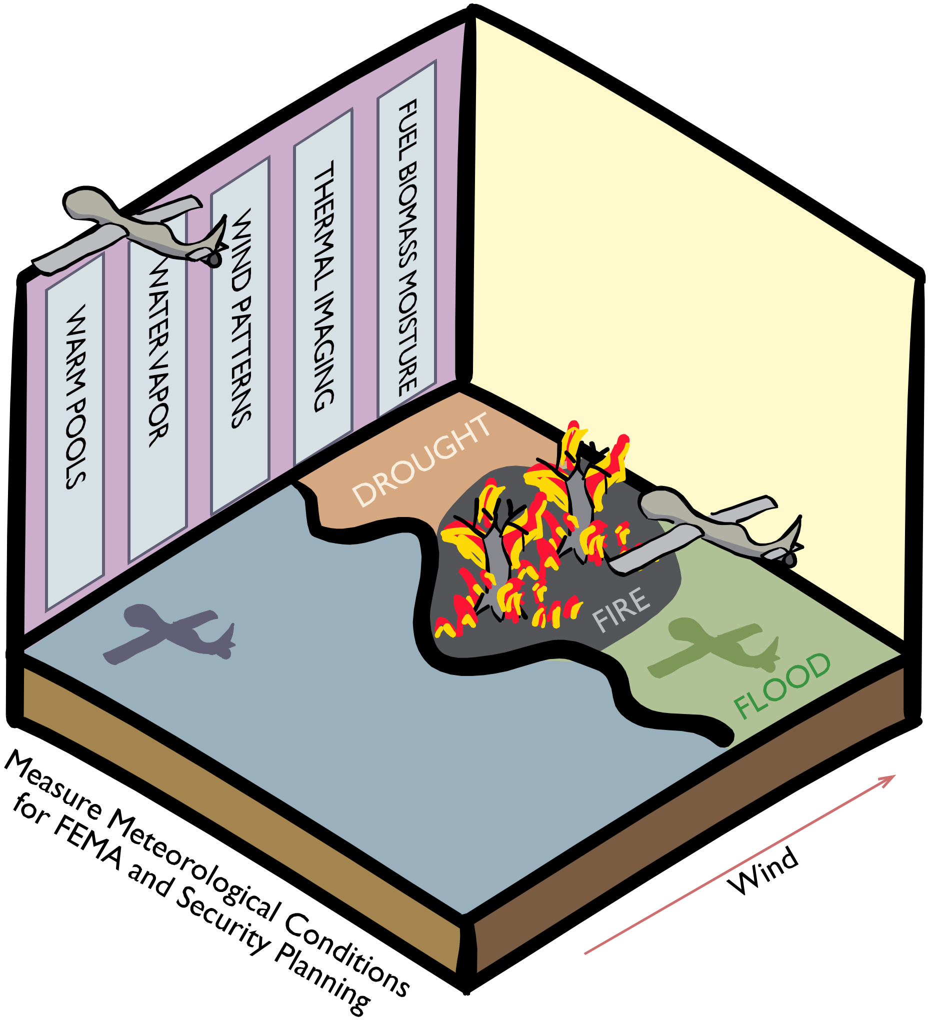
Basic State Climate Profiles



Obstacles

- Communicating the Needs – Funding, Scientists & Public
- Funding
- Sustaining Measurements
- Balancing Regular Monitoring with Flexibility
- FAA (Certification) & International

High Impact Events – Prediction & Mitigation



Obstacles

- FAA – Terrestrial & Flight Corridors
- Proximity Logistics for Deployments
- International ATC
- UAV Ruggedized (all-weather, clouds, precipitation, turbulence, thermal, continuous flights, reliability)
- Remote deployment operations (runway, consumables, etc.)
- Advancement of Technology (capabilities, stream-lined operations)
- Standardization of Payloads & Data Management
- Public acceptance of UAV Operations
- Maintainers of the System (who will "own" and operate the system – UAV ops)
- Frequency Management
- Lack of Advocacy Group to raise awareness

Summary - the Path Forward

The Workshop accomplished its objectives…

- Brought together an outstanding group of scientists and climate change program representatives for valuable discussions
- Identified a number of key climate change science questions and identified capabilities of UAVs that are well suited to help address those questions
- Continued to build momentum in the emerging collaboration among NASA, NOAA, and DOE on global climate change research

The next steps…

- The results of the workshop will be captured as a concise document to help explain the scientific basis of the proposed NASA/NOAA/DOE collaboration
- Additional workshops will be held to address other aspects of future capability requirements such as UAV platform performance and measurement/instrument needs
- NASA/NOAA/DOE will continue to work toward a collaboration and new initiative in global climate change research